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(54) **STRESS RELIEF STRUCTURES IN PACKAGE ASSEMBLIES**

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See application file for complete search history.

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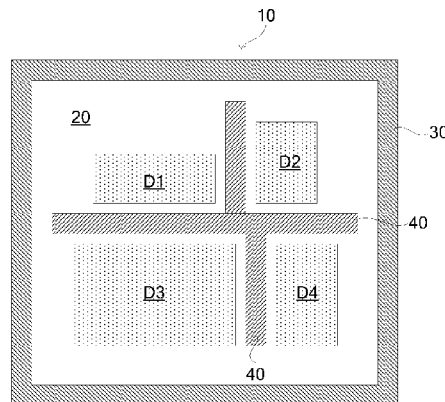
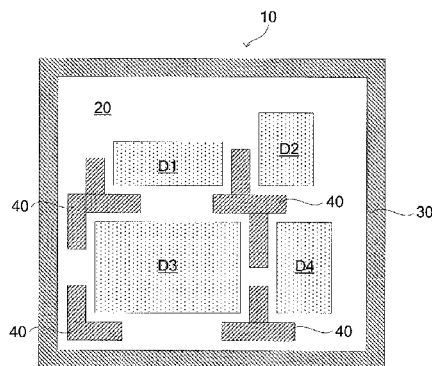
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(57) **ABSTRACT**

A semiconductor package structure, comprises a substrate, a die region having one or more dies disposed on the substrate, and at least one stress relief structure disposed at one or more corners of the substrate, the at least one stress relief structure being adjacent to at least one die of the one or more dies.

**19 Claims, 4 Drawing Sheets**



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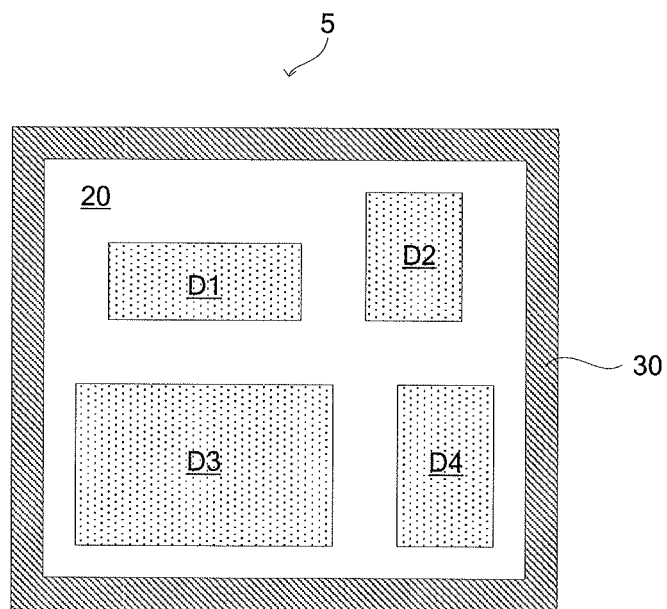


FIG. 1 (Prior Art)

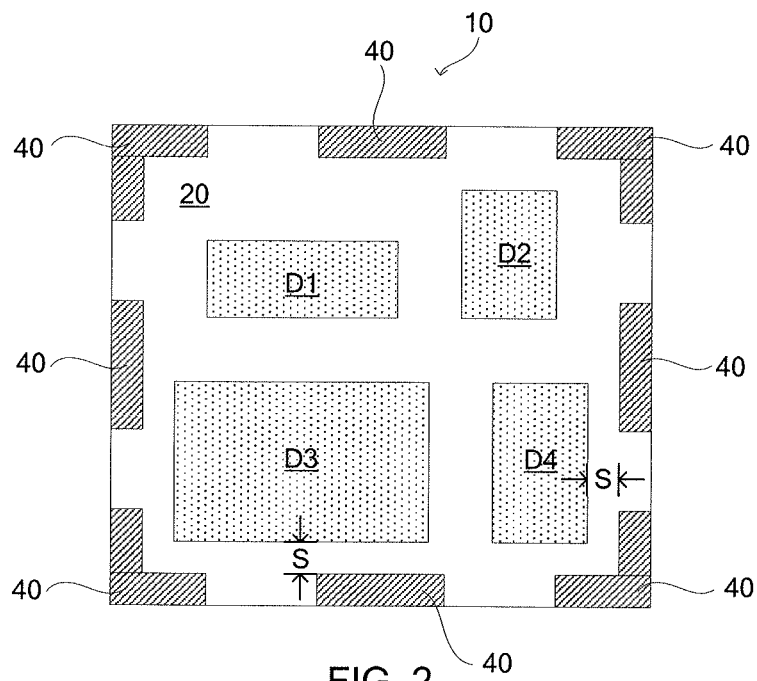


FIG. 2

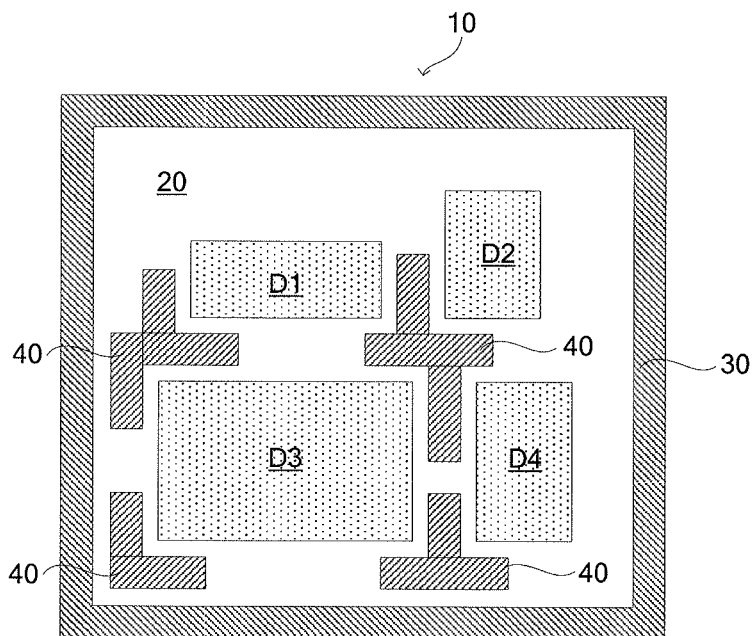
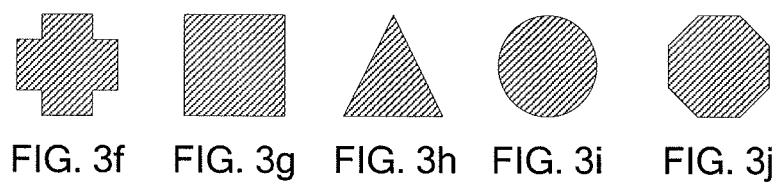
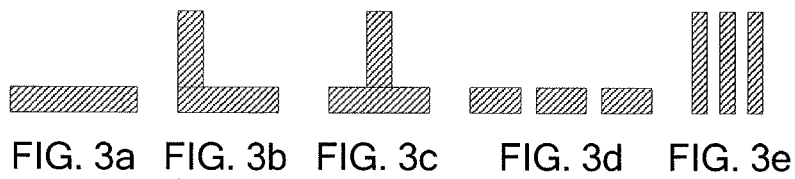


FIG. 4

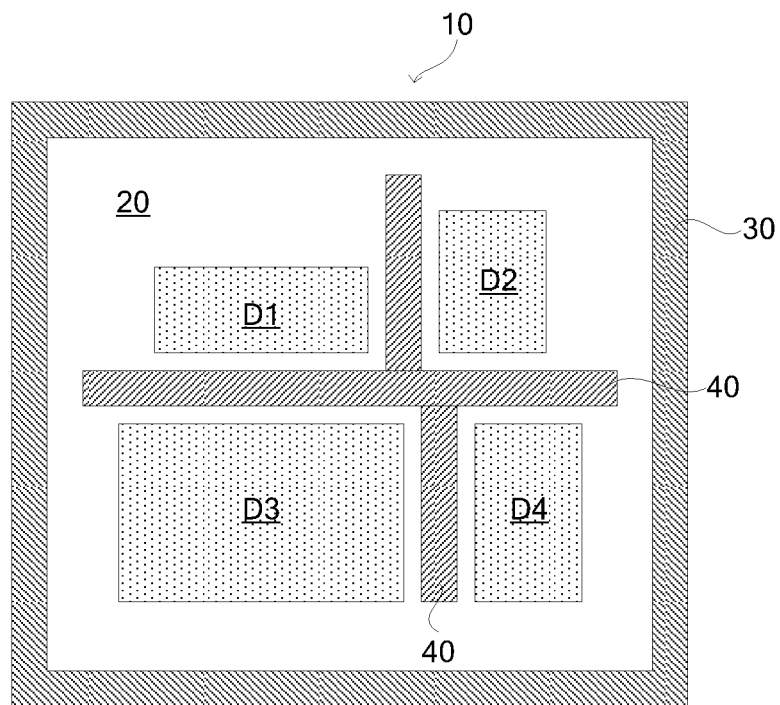


FIG. 5

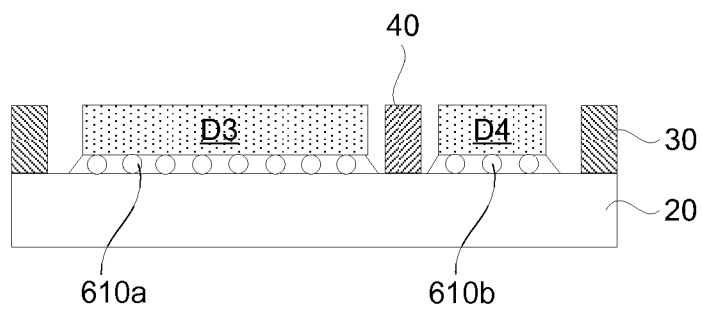


FIG. 6

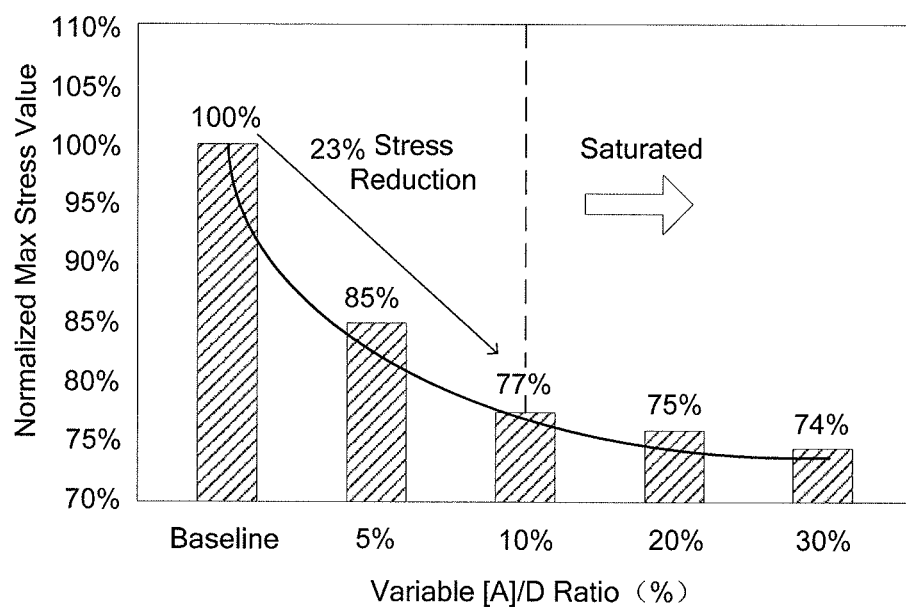


FIG. 7

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## STRESS RELIEF STRUCTURES IN PACKAGE ASSEMBLIES

### FIELD

The disclosure relates generally to the field of packaging structures, and more particularly, to stress relief structures for reducing warpage in package assemblies.

### BACKGROUND

Modern integrated circuits are formed on semiconductor chips. To increase manufacturing throughput and to lower manufacturing costs, the integrated circuits are manufactured in semiconductor wafers, each containing many identical semiconductor chips. After the integrated circuits are manufactured, semiconductor chips are sawed from the wafers and packaged before they can be used.

In typical packaging processes, semiconductor chips or dies are first attached to package substrates. This includes physically securing the semiconductor chips on the package substrates, and connecting bond pads on the semiconductor chips to bond pads on the package substrates. Underfill, which typically comprises epoxy, is used to further secure the bonding. The semiconductor chips may be bonded using either flip-chip bonding or wire bonding.

After the semiconductor chips are bonded onto the package substrates, the solder regions that join the semiconductor chips with the package substrates often suffer from cracking. This is caused by the stress resulting from the difference in coefficients of thermal expansion (CTE) between the package substrates and the semiconductor chips. The difference in CTEs of different layers of the package substrates and the semiconductor chips also results in stresses. The increase in the size of the package substrates and the semiconductor chips results stress increase. As a result of the increased stresses, the solder cracking becomes more severe and delamination may occur between different layers of the semiconductor chips. Particularly, the delamination is likely to occur between low-k dielectric layers in the semiconductor chips.

To reduce the stress caused by the CTE difference between the package substrate and one or more dies a stiffener ring is typically placed on the package substrate around the die(s). FIG. 1 is a top view of a semiconductor package structure 5 with a stiffener ring 30 extending about a perimeter of substrate 20 and surrounding a plurality of dies D1, D2, D3, and D4 on the substrate 20. The stiffener ring 30 seals the dies D1, D2, D3, and D4 from moisture, provides a level of mechanical strength to the semiconductor package structure 5, and provides for global warpage control of the semiconductor package structure 5. Though stiffener ring 30 may provide global warpage control, it may not be sufficient to control local warpages in or around the areas of individual dies D1, D2, D3, and D4. Furthermore, where there is a large die D3 compared to the other dies D1, D2, and D4, the warpage around die D3 may not be adequately controlled by one stiffener ring 30.

### BRIEF DESCRIPTION OF DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It is emphasized that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

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FIG. 1 is a top view of a semiconductor package structure with a stiffener ring surrounding a plurality of dies.

FIG. 2 is a top view of a semiconductor package structure illustrating a layout of stress relief structures on a substrate, according to one embodiment of the present disclosure.

FIG. 3a-3j are top views of various shapes of the stress relief structures, according to various aspects of the present disclosure.

FIG. 4 is a top view of a semiconductor package structure illustrating a layout of stress relief structures on a substrate, according to one embodiment of the present disclosure.

FIG. 5 is a top view of a semiconductor package structure illustrating a layout of stress relief structures on a substrate, according to one embodiment of the present disclosure.

FIG. 6 is a cross-sectional view of the semiconductor package structure of FIG. 5.

FIG. 7 is a graph showing a curve representing stress reduction when various dimensions of stress relief structures are implemented in a semiconductor package, according to an aspect of the present invention.

### DETAILED DESCRIPTION

In the following description, specific details are set forth to provide a thorough understanding of embodiments of the present disclosure. However, one having an ordinary skill in the art will recognize that embodiments of the disclosure can be practiced without these specific details. In some instances, well-known structures and processes are not described in detail to avoid unnecessarily obscuring embodiments of the present disclosure.

Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. It should be appreciated that the following figures are not drawn to scale; rather, these figures are merely intended for illustration.

FIG. 2 is a top view of a semiconductor package structure illustrating a layout of stress relief structures on a substrate, according to one embodiment of the present disclosure. Semiconductor package structure 10 includes the plurality of dies D1, D2, D3, and D4 disposed on the substrate 20 and a plurality of stress relief structures 40 disposed around the dies D1, D2, D3, and D4. Stress relief structures 40 provide local stress relief and/or warpage control to the semiconductor package structure 10 that may be caused by stress resulting from the difference in coefficients of thermal expansion (CTE) between the substrate 20 and dies D1, D2, D3, and/or D4. Further, stress relief structures 40 may improve the stress redistribution in semiconductor package structure 10 so that local stresses may be redistributed to other regions of the semiconductor package structure. According to one embodiment, stress relief structure 40 is disposed at at least one corner of substrate 20 with at least one of the dies D1, D2, D3 or D4 being adjacent to the stress relief structure 40. The stress relief structure 40 provides for stress relief at that particular corner. According to another embodiment, a stress relief structure 40 is disposed at the four corners of substrate 20, with at least one of the dies D1, D2, D3, or D4 being adjacent to a stress relief structure 40. The spacing S between a die and a stress relief structure 40 may be greater than about

2  $\mu\text{m}$ , or even greater than about 3  $\mu\text{m}$ , to prevent stress relief structure **40** from being shorted to dies D1, D2, D3, or D4. It is realized, however, that the dimensions recited throughout the description are merely examples, and may be changed to other suitable values.

According to one or more embodiments, stress relief structures **40** are formed using photolithography, patterning, and etching techniques. Stress relief structures **40** may be disposed on substrate **20** by means of an adhesive material (not shown) and may comprise any material suitable for attaching stress relief structure **40** onto substrate **20**, such as epoxies, urethane, polyurethane, silicone elastomers, and the like. According to one embodiment, the bonding of stress relief structures **40** onto substrate **20** includes coating an adhesive material on a surface of substrate **20**. According to one or more embodiments, a curing process is then performed to cure the adhesive material. The adhesive material may also have a good thermal conductivity, for example, greater than about 10 W/m $^{\circ}\text{C}$ .

Stress relief structure **40** may be formed of a thermally conductive material such as for example, metal, tungsten, aluminum, aluminum alloy, polysilicon, silicide, tantalum, refractory metal, copper, copper alloy, gold, gold alloy, tantalum nitride, titanium, titanium nitride, nickel, compounds thereof, alloys thereof, or combinations thereof. The scope of the present disclosure is not limited to the above-mentioned materials and other materials are also contemplated such as, for example ceramic, solder, or plastic. The materials used for the stress relief structures **40** may be the same throughout the stress relief structures **40** or may vary at different locations in the stress relief structures **40**.

According to one or more embodiments, stress relief structures **40** may have good thermal conductivity, which may be greater than about 20 W/m $^{\circ}\text{C}$ ., for example. Alternatively, stress relief structures **40** have a thermal conductivity equal to or greater than the thermal conductivity of silicon. According to some embodiments, stress relief structure **40** includes substantially a same material as either substrate **20** or dies D1, D2, D3, or D4.

According to one or more embodiments, stress relief structure **40** may have irregular or regular shapes, such as, for example a rectangle (FIG. 3a), an L-shape (FIG. 3b), a T-shape (FIG. 3c), a broken strip (FIG. 3d), a rectangular array (FIG. 3e), a cross (FIG. 3f), a square (FIG. 3g), a triangle (FIG. 3h), a circle (FIG. 3i), and a polygon (FIG. 3j). A combination of the above-mentioned shapes or other shapes based on the spirit of the present disclosure and suitable for reducing the stress caused by the CTE mismatch between the substrate and the die(s) are also contemplated. Stress relief **40** may also have random sizes, random shapes, random thicknesses, and/or random orientations and may be placed randomly in location and orientation. Preferably, stress relief structures **40** will be maximized in accordance with design rules for the layout of the semiconductor package structure.

Still referring to FIG. 1, according to another embodiment of the present invention, stress relief structure **40** is disposed on a periphery of substrate **20**, at approximately a mid-section thereof, with at least one of the dies D1, D2, D3, or D4 being adjacent to a stress relief structure **40**. According to another embodiment, a stress relief structure **40** is disposed on a periphery of substrate **20**, at approximately two or more mid-sections thereof, with at least one of the dies D1, D2, D3, or D4 being adjacent to a stress relief structure **40**.

FIG. 4 is a top view of a semiconductor package structure illustrating a layout of stress relief structures on a substrate, according to another embodiment of the present disclosure. Semiconductor package structure **10** includes a plurality of

dies D1, D2, D3, and D4 disposed on a substrate **20**, with die D3 being the largest die and a plurality of stress relief structures **40** disposed on substrate **20**. A stress relief structure **40** is disposed at at least one corner, e.g., a corner of die D3, providing for stress relief at the particular corner of die D3. According to another embodiment, a stress relief structure **40** is disposed at the four corners of die D3, providing for stress relief at the four corners of die D3. In yet another embodiment, the semiconductor package structure **10** of the present disclosure includes both the stress relief structures **40** and the stiffener **30** for additional reduction of the stress caused by the CTE difference between the semiconductor package substrate **10** and one or more dies D1-D4. As discussed above, a stiffener ring provides for global warpage control of the semiconductor package structure but may not be sufficient to control local warpages in or around the areas of individual dies D1, D2, D3, and D4, especially if the die is a large die compared to the other dies.

FIG. 5 is a top view of a semiconductor package structure illustrating a layout of stress relief structures on a substrate, according to another embodiment of the present disclosure. A stress relief structure **40** is disposed in close proximity to at least one of the dies D1, D2, D3, or D4 with the stress relief structure **40** being a strip extending substantially from close to one edge of the substrate **20** to an opposite edge of the substrate **20**. One or more stress relief structure **40** may run between any two or more dies, according to one embodiment. In another embodiment, the semiconductor package structure **10** of the present disclosure includes both the stress relief structures **40** and the stiffener **30** for additional reduction of the stress caused by the CTE difference between the semiconductor package substrate **10** and one or more dies D1-D4. FIG. 6 is a cross-sectional view of the semiconductor package structure **10** of FIG. 5. FIG. 6 depicts a stress relief structure **40** running between dies D3 and D4. As depicted in FIG. 6, die D3 is bonded on the substrate **20** through solder region **610a**, and die D4 is bonded on the substrate **20** through solder region **610b**.

Experiments have been performed to evaluate the effect of the stress relief structures on the stress reduction of the semiconductor package structure. FIG. 7 is a graph showing a curve representing stress reduction when various dimensions of stress relief structures are implemented in a semiconductor package structure, according to an aspect of the present invention. The vertical axis represents a stress value and the horizontal axis represents a variable A/D ration (%). It was observed that the reduction of a maximum stress value of the die is dependent on a stress relief structure width [A]. Furthermore, the stress relief structure width [A] may be designed according to various die with D. As shown in FIG. 7, the higher the ratio of A to die width D results in a higher stress reduction. As indicated by a downward arrow, there is a 23% stress reduction from baseline to 10%. The results indicate that stress relief structures **40** have a significant effect in reducing the stress of the semiconductor package structure and therefore enhancing the reliability of the semiconductor package structure.

According to one or more embodiments, the selecting of the placements of the stress relief structures **40** may be performed automatically using a software algorithm. The selecting of the placements using the software algorithm may be performed in accordance with at least one predetermined design rule taking into account the minimum spacing around a particular die. Further, the selecting of the placements using the software algorithm may be performed by a layout tool during a layout process.



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One or more embodiments of the present disclosure may provide numerous advantages, including (but not limited to) reducing the stress caused by the difference in coefficients of thermal expansion (CTE) between the package substrate and one or more dies. Teachings of the present disclosure are particularly applicable to large semiconductor package structures where with the increase in the size of the package substrates and the dies, the stress increases. As a result of the increased stresses, the solder cracking becomes more severe and delamination may occur between different layers of the chips. One or more embodiments of the present disclosure help strengthen the semiconductor package structure and helps reduce the likelihood of cracking and peeling. Moreover, one or more embodiments increase the amount of stress a semiconductor package structure can handle. Further, stiffener rings may provide global stress relief to the semiconductor package structure but may not provide adequate local stress relief. Layout of the stress relief structures in one or more embodiments provide for local stress relief and/or warpage control to the semiconductor package structure. Further still, one or more embodiments of the present disclosure improve the output yield and reliability.

It is understood that the stress relief structures 40 described above in conjunction with FIGS. 2, 4, and 5 are merely exemplary. In some embodiments, additional stress relief structures 40 (not shown) are disposed adjacent to the ones shown in these figures. The additional stress relief structures 40, in one or more embodiments, may have shapes exactly as those shown in the figures or shapes similar to those shown in the figures. Furthermore, the additional stress relief structure or structures 40, in one or more embodiments, is/are aligned or misaligned from those shown in the figures.

The present disclosure has described various exemplary embodiments. According to one embodiment, a semiconductor package structure, comprises a substrate, a die region having one or more dies disposed on the substrate, and at least one stress relief structure disposed at one or more corners of the substrate, the at least one stress relief structure being adjacent to at least one die.

According to another embodiment, a semiconductor package structure, comprises a substrate, a die region having one or more dies disposed on the substrate, and at least one stress relief structure disposed on a periphery of the substrate, at approximately one or more mid-sections of the substrate, the at least one stress relief structure being adjacent to at least one die of the one or more dies.

According to yet another embodiment, a semiconductor package structure, comprises a substrate, a die region having one or more dies, with at least one die of the one or more dies being larger than the other dies, the one or more dies disposed on the substrate, and at least one stress relief structure disposed adjacent to one or more corners of the at least one die larger than the other dies.

According to yet another embodiment, a semiconductor package structure, comprises a substrate, a die region having one or more dies disposed on the substrate, and at least one stress relief structure disposed in close proximity to at least one die of the one or more dies, the stress relief structure is a strip extending substantially from close to one edge of the substrate to the die region.

In the preceding detailed description, specific exemplary embodiments have been described. It will, however, be apparent to a person of ordinary skill in the art that various modifications, structures, processes, and changes may be made thereto without departing from the broader spirit and scope of the present disclosure. The specification and drawings are, accordingly, to be regarded as illustrative and not restrictive.

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It is understood that embodiments of the present disclosure are capable of using various other combinations and environments and are capable of changes or modifications within the scope of the claims.

What is claimed is:

1. A semiconductor package structure, comprising:

a substrate;

a solder region;

one or more dies bonded on the substrate through the solder region; and

two or more stress relief structures, each stress relief structure of the stress relief structures being formed on or bonded onto a surface of the substrate and being disposed adjacent to at least one die of the one or more dies, wherein a first stress relief structure of the two or more stress relief structures has a different shape from a second stress relief structure of the two or more stress relief structures,

wherein

upper surfaces of the stress relief structures are unconnected; and

at least one stress relief structure of the two or more stress relief structures is disposed adjacent to a corner of the at least one die, and the at least one stress relief structure comprises:

a first portion extending along a first side of the at least one die, the first side being associated with the corner of the at least one die; and

a second portion extending along a second side of the at least one die, the second side being associated with the corner of the at least one die,

wherein the two or more stress relief structures individually comprise a material selected from the group consisting of a thermally conductive material, metal, tungsten, aluminum, aluminum alloy, polysilicon, silicide, tantalum, refractory metal, copper, copper alloy, gold, gold alloy, TaN, titanium, TiN, nickel, and combinations thereof.

2. The semiconductor package structure of claim 1, wherein the stress relief structures have irregular shapes selected from the group consisting of a square, a rectangle, a triangle, a circle, an L-shape, a T-shape, a broken strip, a rectangular array, a cross, and a polygon.

3. The semiconductor package structure of claim 1, wherein the stress relief structures have random sizes, random thicknesses, and/or random orientations.

4. The semiconductor package structure of claim 1, wherein the stress relief structures comprise substantially a same material as the substrate and/or the one or more dies.

5. A semiconductor package structure, comprising:

a substrate;

a solder region;

a plurality of dies, with at least one die of the plurality of dies being larger than the other dies of the plurality of dies, the plurality of dies being bonded on the substrate through the solder region;

an underfill between each die of the plurality of dies and the substrate; and

two or more stress relief structures, each stress relief structure of the stress relief structures being formed on or bonded onto a surface of the substrate and being disposed adjacent to the at least one die of the plurality of dies, wherein at least a first stress relief structure of the two or more stress relief structures are spaced from each die of the plurality of dies in a direction parallel to a top

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surface of the substrate, and a second stress relief structure of the two or more stress relief structures is spaced from the underfill, wherein

upper surfaces of the stress relief structures are unconnected; and

at least one stress relief structure of the two or more stress relief structures is disposed adjacent to a corner of the at least one die, and the at least one stress relief structure comprises:

a first portion extending along a first side of the at least one die, the first side being associated with the corner of the at least one die; and

a second portion extending along a second side of the at least one die, the second side being associated with the corner of the at least one die.

6. The semiconductor package structure of claim 5, wherein the stress relief structures comprise a material selected from the group consisting of a thermally conductive material, metal, tungsten, aluminum, aluminum alloy, polysilicon, silicide, tantalum, refractory metal, copper, copper alloy, gold, gold alloy, TaN, titanium, TiN, nickel, and combinations thereof.

7. The semiconductor package structure of claim 5, wherein the stress relief structures have irregular shapes selected from the group consisting of a square, a rectangle, a triangle, a circle, an L-shape, a T-shape, a broken strip, a rectangular array, a cross, and a polygon.

8. The semiconductor package structure of claim 5, wherein the stress relief structures have random sizes, random thicknesses, and/or random orientations.

9. The semiconductor package structure of claim 6, wherein the stress relief structures are bonded onto the substrate by an adhesive.

10. The semiconductor package structure of claim 9, wherein the adhesive has a thermal conductivity greater than about 10 W/m° C.

11. The semiconductor package structure of claim 5, wherein the stress relief structures are bonded onto the substrate by an adhesive.

12. The semiconductor package structure of claim 11, wherein the adhesive has a thermal conductivity greater than about 10 W/m° C.

13. A semiconductor package structure, comprising:

a substrate;

a solder region;

one or more dies bonded on the substrate through the solder region;

an underfill between each die of the one or more dies and the substrate; and

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two or more stress relief structures, each stress relief structure of the stress relief structures being formed on or bonded onto a surface of the substrate and being disposed adjacent to at least an identified largest die of the one or more dies, wherein at least a first stress relief structure of the two or more stress relief structures is spaced from each die of the one or more dies in a direction parallel to a top surface of the substrate, and at least a second stress relief structure of the two or more stress relief structures spaced from the underfill,

wherein

upper surfaces of the stress relief structures are unconnected; and

at least one stress relief structure of the two or more stress relief structures is disposed adjacent to a corner of the identified largest die, and the at least one stress relief structure comprises:

a first portion extending along a first side of the identified largest die, the first side being associated with the corner of the identified largest die; and

a second portion extending along a second side of the identified largest die, the second side being associated with the corner of the identified largest die.

14. The semiconductor package structure of claim 13, wherein the stress relief structures comprise substantially a same material as the package substrate and/or the one or more individual dies.

15. The semiconductor package structure of claim 13, wherein the stress relief structures comprise a material comprising a thermally conductive material, metal, tungsten, aluminum, aluminum alloy, polysilicon, silicide, tantalum, refractory metal, copper, copper alloy, gold, gold alloy, TaN, titanium, TiN, nickel, or combinations thereof.

16. The semiconductor package structure of claim 13, wherein the stress relief structures are bonded onto the package substrate by an adhesive.

17. The semiconductor package structure of claim 16, wherein the adhesive has a thermal conductivity greater than about 10 W/m° C.

18. The semiconductor package of claim 1, further comprising an underfill between each die of the one or more dies and the substrate, wherein the at least one stress relief structure is spaced from the underfill.

19. The semiconductor package of claim 1, wherein a spacing between at least one stress relief structure of the stress relief structures and a nearest die of the one or more dies is greater than about 2 μm.

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